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Integrity of Benthic Macroinvertebrate Communities in Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial

Eastern Rivers and Mountains Network 2008 Summary Report

Natural Resource Data Series NPS/ERMN/NRDS—2009/XXX

ON THE COVER
Blair Gap Run at Allegheny Portage Railroad National Historic Site
Photograph by: Caleb Tzilkowski.

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Abstract

During 2008, the Eastern Rivers and Mountains Network (ERMN) of the National Park Service (NPS) began monitoring benthic macroinvertebrate (BMI) communities in wadeable streams throughout its nine parks. Three targeted (i.e., non-random) sites at ALPO and one targeted site at JOFL were chosen in consultation with Kathy Penrod, the Natural Resource Specialist at the parks. In addition to BMI samples, core water quality data (i.e., temperature, dissolved oxygen, pH, and specific conductance) were collected and reach-scale habitat was characterized.

Water in the unnamed tributary (UNT) to South Fork Little Conemaugh River at JOFL had considerably greater specific conductance (239.4 µS/cm) than the ALPO sites. Otherwise, core water quality parameters at ALPO and JOFL sites were characteristic for forested Pennsylvania watersheds with similar geologic characteristics. Relationships among core parameters were also typical – specific conductance generally decreased with decreasing pH whereas dissolved oxygen concentrations (DO) consistently decreased with increasing water temperature. Benthic macroinvertebrate communities throughout ALPO and JOFL streams had Macroinvertebrate Biotic Integrity Index (MBII) values that ranged from 23.6 (UNT to SFLCR) to 53.7 (Millstone Run). We compared these results with those from the recently conducted USEPA Wadeable Streams Assessment (WSA). There were methodological differences between the ERMN protocol and the WSA which likely resulted in conservative estimates of WSA condition class (i.e., good, fair, poor) for ALPO and JOFL streams based on the MBII. Based on MBII thresholds for the Southern Appalachians Ecoregion, only one stream (Millstone Run) was considered to be in the “Good” condition class. Both sites located on Blair Gap Run were considered to be in the “Fair” condition class whereas the JOFL site was in the “Poor” condition class.

Introduction

During 2008, the Eastern Rivers and Mountains Network (ERMN) of the National Park Service (NPS) began monitoring benthic macroinvertebrate (BMI) communities in wadeable streams throughout its nine parks. This monitoring effort is a component of the ERMN Vital Signs monitoring program (Marshall and Piekielek 2007) as part of the nationwide NPS Inventory and Monitoring Program (Fancy et al. 2009).

One of the primary objectives of the ecological monitoring program in the ERMN is to evaluate status and trends in the condition of tributary watersheds flowing into and through member parks. Watershed condition is evaluated using measures of ecosystem integrity, including streamside bird species and communities (Mattsson and Marshall 2009), forest structure and composition (Perles et al. 2009), stream-dwelling benthic macroinvertebrates (Tzilkowski et al. 2009), stream chemistry, and watershed landuse, type, and configuration (Marshall and Piekielek 2007). A primary purpose of the benthic macroinvertebrate (BMI) monitoring protocol is to support the antidegradation or restoration of ERMN aquatic communities and their habitat (including water quality) by communicating monitoring program results to appropriate regulatory state and federal agencies.

Benthic macroinvertebrates are aquatic invertebrate animals larger than microscopic size that live on or within the stream bottom (benthos), and because they are a vital component of all functioning stream ecosystems, they are often used as indicators of ecosystem integrity. Types of BMI that are commonly used for water quality assessment include arthropods (insects, arachnids, and crustaceans), worms, clams, and snails. In addition to being instrumental to nutrient and carbon dynamics, BMI are an important link between basal resources (e.g., algae and detritus) and higher trophic levels (e.g., fish and birds) in stream food webs. Because BMI have been by far the most commonly used group for biological monitoring of aquatic ecosystems (Carter and Resh 2001), many metrics have been evaluated with respect to natural variation and responses to various sources of human-induced degradation. Given the proven ability to derive ecosystem integrity based on measures of BMI assemblage structure and composition, combined with the relatively low cost to sample, BMI are almost certainly the single best biological group to assess and monitor the ecological integrity of small and mid-sized streams.

At the time that this report was prepared, the BMI-monitoring protocol (Tzilkowski et al. 2009) had been developed, written, and received internal peer review but had not undergone the final peer review process. This report was intended to provide preliminary results to the Natural Resource Manager at Allegheny Portage Railroad National Historic Site (ALPO) and Johnstown Flood National Memorial (JOFL). The preliminary nature of data presented in this report should be considered prior to its use or dissemination.

Methods

Although a brief overview of the BMI monitoring methods is provided here, a detailed rationale of the sampling design and methods, in addition to Standard Operating Procedures, are provided in the BMI Monitoring Protocol (Tzilkowski et al. 2009). Much of this protocol is based on protocols developed by the U.S. Geological Survey (Moulton et al. 2000, Moulton et al. 2002) and Bowles et al. (2006) because those protocols and programs have already undergone considerable evaluation and revision. We modified those protocols to fit the character of ERMN parks and anticipated monitoring resources.

Site Selection

There are two types of sampling sites in the BMI Monitoring Program – probabilistic (i.e., stratified-random) sites and non-random "targeted" sites. The probability-based design was developed by Mattsson and Marshall (2009) for the ERMN Streamside Bird Monitoring Program but was not used at ALPO or JOFL due to the relatively small size of the parks. Instead, three targeted sites at ALPO (Figure 1) and one targeted site at JOFL (Figure 2) were chosen in consultation with Kathy Penrod, the Natural Resource Specialist at the parks. Justification for selecting the ALPO sites was as follows: (1) the downstream-most sampling location on Blair Gap Run (Foot of Ten) was chosen to represent the condition of BMI communities at the park outflow point of Blair Gap Run, (2) the upstream site on Blair Gap Run (Muleshoe) was chosen because it was immediately downstream of the mixing point of the two largest tributaries to Blair Gap Run, and (3) the Millstone Run site was chosen because it was collocated with the Streamside Bird monitoring site located there. The JOFL site was chosen because it was located on the largest of three small tributaries to the South Fork Little Conemaugh River within the park. That stream was expected to experience less periodic drying during the fall than the other streams.

Field Methods

The sampling unit for the BMI monitoring program is the stream reach which, for the ERMN program, is defined as a longitudinal section of stream chosen to represent a uniform set of physical, chemical, and biological conditions within a stream segment. The length of sampled reaches differs among watersheds but their length is proportional (i.e., 40 X) to stream width. Minimum and maximum reach lengths are 150 m and 500 m respectively.

Sampling was conducted at ALPO and JOFL during October and November 2008 respectively. The ERMN method for collecting BMI throughout ALPO and JOFL is termed semi-quantitative richest-targeted habitat (RTH, Moulton et al. 2002) sampling which is a type of disturbance-removal sampling. Although similar to more common kick sampling methods, RTH sampling calls for consistent and thorough collection of BMI from a fixed area; thus, it is considered a more precise method and allows for estimation of stream productivity unlike many other sampling methods. Many BMI disturbance-sampling methods are qualitative, (not quantitative) and are comparatively inconsistent because there is no measurement of sampling area – instead, those methods usually rely on a timed sampling effort. For the RTH method, five discrete samples are collected from riffles throughout the reach and are ultimately composited into a single homogenous sample. Ideally, discrete samples are taken from different riffles, but if fewer than five riffles are present, samples may be taken from the same riffle. Physical conditions (i.e., depth, flow, and substrate) are recorded at each sampling location and should be as similar as possible among replicates. Sampling is conducted by defining a 0.25 m^2 sampling area with a template and then disturbing substrate within that area so that BMI are dislodged and then drift into a net placed downstream of the sampling area. The composited samples result in 1.25 m^2 of sampled area at each site.

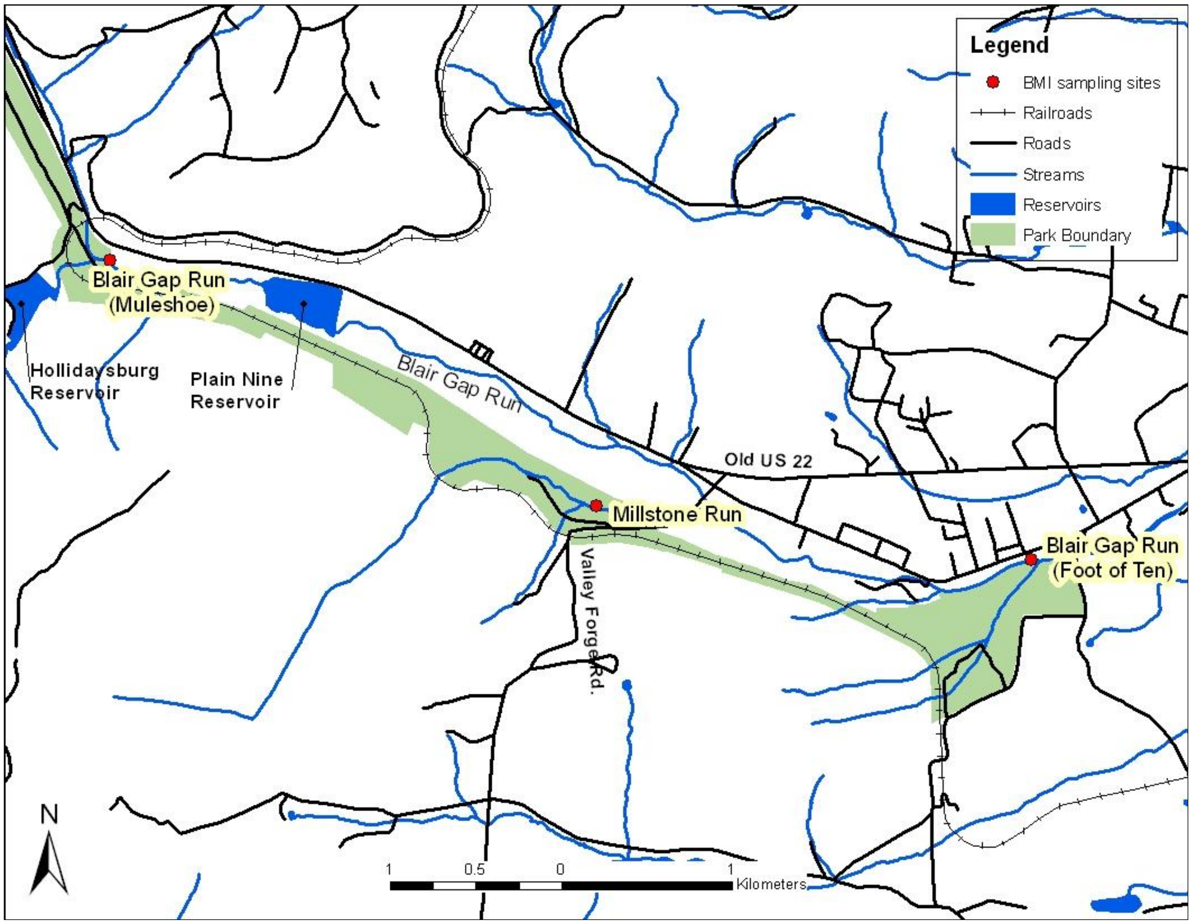

Figure 1. Benthic macroinvertebrate sampling sites throughout Allegheny Portage Railroad National Historic Site.

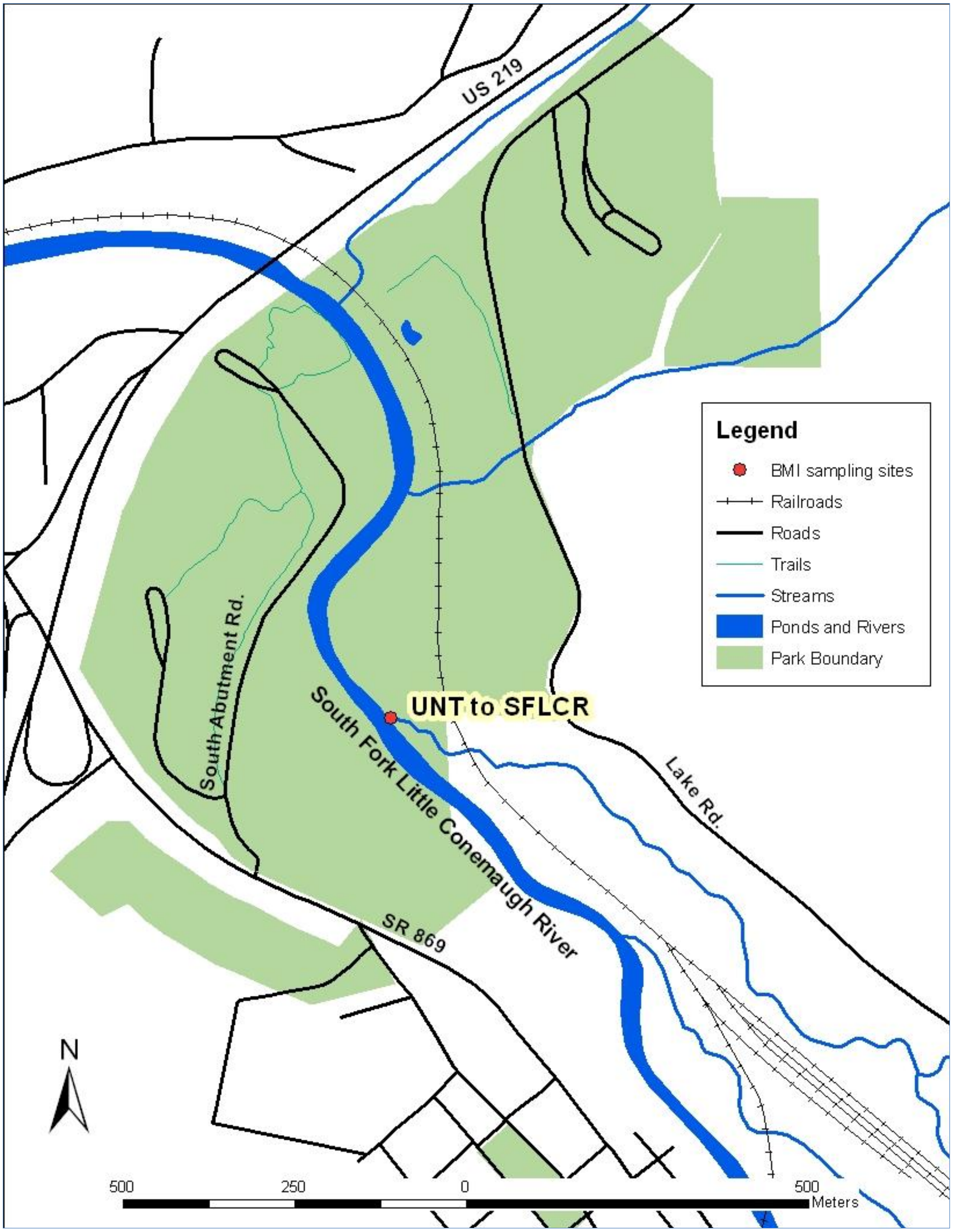

Figure 2. Benthic macroinvertebrate sampling site located on the unnamed tributary to South Fork Little Conemaugh River (UNT to SFLCR) at Johnstown Flood National Memorial.

In addition to BMI samples, core water quality data (i.e., temperature, dissolved oxygen, pH, and specific conductance) are collected and reach-scale habitat is characterized using the U.S. Environmental Protection Agency rapid bioassessment method (Barbour et al. 1999). Samples are processed in the field by using an elutriation method to remove mineral materials and large organic matter (e.g., whole leaves and sticks). Samples are preserved in 95% ethanol, packed carefully, and transported back to the laboratory for processing and identification.

Laboratory Methods

Laboratory methods for processing samples in the ERMN BMI Program rely a great deal on procedures developed by the USGS (Moulton et al. 2000). A fixed-count subsample of 300 $\pm$ 20% individuals are sorted and identified from each sample. The relatively large subsample size yields data that meets quality standards (i.e. precision and accuracy) required by most monitoring programs; however, processing and identifying additional individuals (> 300) does not typically yield enough additional information to justify the added effort (Moulton et al. 2000). Generally, BMI were identified to genus using standard dichotomous keys, but some groups (e.g., Chironomidae, Oligochaeta) were identified to coarser taxonomic levels. Microsoft Access 2007 is the primary software used for storing and managing ERMN BMI and stream habitat data, whereas the Invertebrate Data Analysis System (IDAS *version 5*, U.S. Geological Survey, Raleigh, NC) was used for resolving taxonomic ambiguity issues and calculating metrics that describe the structure and diversity of BMI communities.

Data Analysis

We calculated all BMI community metrics with IDAS and calculated the Macroinvertebrate Biotic Integrity Index (MBII; Klemm et al. 2003) using Microsoft Excel 2007. The MBII was developed by the U.S. Environmental Protection Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP) and was ultimately used for the USEPA's Wadeable Stream Assessment (WSA; USEPA 2006; Herlihy et al. 2008).

The rationale behind biotic integrity indices is that a suite of metrics that represent community structure, pollution tolerance, functional feeding groups and habitat occurrences, life history strategies, disease, and density provide insights regarding how biological communities respond to different natural and anthropogenic stressors (Klemm et al. 2003). A common stream bioassessment practice is to compare BMI community metrics from candidate streams to the same metrics from reference streams. Reference streams are "least disturbed," similarly sized streams within comparable geographic and geologic settings that provide an estimate of least-impaired stream communities. Departure of the sampled BMI community from expected BMI community composition (i.e., reference streams) serves as a measure of stream impairment. The MBII is one such index that uses reference streams to assess stream impairment.

The MBII was chosen for use in the ERMN because it was developed for upland and lowland streams dominated by riffle habitat in the Mid-Atlantic Highlands Region (MAHR). Moreover, the MBII was based on a large dataset of 574 wadeable stream reaches and was thoroughly tested. The MBII is a broadly applicable measure of stream impairment because it is based on several factors that affect aquatic communities throughout the MAHR. Impaired and reference streams for the MBII were identified by Klemm et al. (2003) using water chemistry, qualitative habitat, and minimum organism count criteria. Impaired reaches were defined by meeting any one of the following criteria: pH <5, chloride >1000 µeq/L, sulfate >1000 µg/L, total phosphorous >100 µg/L, total nitrogen >5000 µg/L, or a mean qualitative habitat score <10 (of a possible 20). Reference reaches met all of the following criteria (Klemm et al. 2003): sulfate <400 µg/L, Acid Neutralizing Capacity (ANC) >50 µeq/L, chloride <100 µeq/L, total phosphorous <20 µg/L, total nitrogen <750 µg/L, mean qualitative habitat score >15, and at least 150 organisms.

The MBII uses seven metrics selected from the 100 that are commonly used by governmental agencies throughout the MAHR. The metrics chosen were those that performed best in terms of range, precision, responsiveness to various human-induced disturbances, relationship to catchment area, and redundancy (Table 2; Klemm et al. 2003). Most MBII metrics are counts or proportions of taxa in the community that are characterized as tolerant or intolerant to human perturbations; however, one of the metrics (Macroinvertebrate Tolerance Index; MTI) is more complex because it incorporates values (0–10) for each taxon with respect to pollution tolerance, weighted by taxon abundance, and results in higher scores as the proportion of taxa tolerant to general pollution increases (Klemm et al. 2003). Pollution Tolerance Values (PTV) incorporated in the MTI were average tolerances to "various types of stressors" (Klemm et al. 2002).

Table 1. Macroinvertebrate Biotic Integrity Index metric descriptions and their directions of response to increasing human perturbation (Response) from Klemm et al. (2003).

Metric	Description	Response
Ephemeroptera richness	Number of Ephemeroptera (mayfly) taxa	Decrease
Plecoptera richness	Number of Plecoptera (stonefly) taxa	Decrease
Trichoptera richness	Number of Trichoptera (caddisfly) taxa	Decrease
Collector-filterer richness	Number of taxa with a collecting or filtering-feeding strategy	Decrease
Percent non-insect individuals	Percent of individuals that are not insects	Increase
Macroinvertebrate Tolerance Index	$\sum_i p_i t_i$, where p_i is the proportion of individuals in taxon *i* and t_i is the pollution tolerance value (PTV) for general pollution	Increase
Percent five dominant taxa	Percentage of individuals in the five numerically dominant taxa	Increase

There are important qualifications that should be considered while interpreting the 2008 ALPO and JOFL data with the MBII. We present MBII ranges from the WSA (Herlihy et al. 2008) as points of reference; however, it must be recognized that our sampling methods were similar but not identical to those used to develop (Klemm et al. 2003) or apply the MBII for the WSA (Herlihy et al. 2008). An often encountered difficulty among BMI monitoring or assessment programs is that comparisons are made among datasets that have been compiled by different researchers using different methods. This reality has become increasingly accepted recently (Carter and Resh 2001), but is unfortunately not always recognized.

We do not yet know the degree to which methodological differences influence the comparability of ERMN data to other studies that use the MBII (e.g., WSA). We speculate that ALPO and JOFL MBII scores are likely to be consistently low compared to studies where sampling is conducted during the spring. Because most aquatic insects are in early stages of development during the fall, taxonomic resolution is expected to be lower for fall samples relative to spring samples. Often, larvae in fall samples cannot be distinguished among species or genera and must be "lumped" at the family level. During the spring, most aquatic insects are near emergence and in late stages of larval development; consequently, genera and species can be identified more easily and confidently than in the fall. Another important difference between ERMN methods and the methods used for MBII development is that Klemm et al. (2003) indentified chironomid midges to genus whereas chironomids were only identified to family for ALPO and JOFL samples. What these two differences likely lead to is lower richness scores for several taxa (especially Chironomidae), and because the MBII is largely influenced by richness metrics, the ALPO and JOFL MBII scores were likely also lower. Regardless of comparability to other studies, the MBII and its constituent metrics reflect the condition of ALPO and JOFL streams relative to each other, and to themselves through time.

We also present three other commonly used BMI community metrics (taxa richness, Shannon's Diversity and Evenness) for comparison because they are likely to be familiar to most readers of this report. Taxa richness was the combined number of unique taxa (usually genera). Shannon's diversity and evenness were calculated with IDAS using formulae provided by Brower and Zar (1984), which were:

Shannon's Diversity (H`): information theory-based index that measures the "uncertainty" of a taxon selected at random from the community. High diversity is associated with high uncertainty and low diversity with low uncertainty. This index is the equivalent of the Brillouin's diversity index, but it is intended for use when the abundance data come from a random sample of the community or subcommunity.

$$H` = (N \log_{10} N - \Sigma\, n \log_{10} n)/N$$

Shannon's Evenness (J`): ratio of the observed Shannon diversity to the maximum possible diversity (that is, diversity when individuals are distributed as evenly as possible among the species). Like the Shannon diversity index, this measure is intended to be used when the abundance data come from a random sample or the community or subcommunity

$$J` = H`/H_{max}` \text{ where } H_{max}` = \log_{10} S$$

Abbreviations used in formulae: S = number of taxa in sample, n = abundance of an individual taxon, N = total number of individuals in sample, c = integer portion of N/S, r = remainder of N/S.

Results

Benthic Macroinvertebrate Communities

Benthic macroinvertebrate communities throughout ALPO and JOFL streams had MBII values that ranged from 23.6 (UNT to SFLCR) to 53.7 (Millstone Run, Figure 2). Based on MBII thresholds for the Southern Appalachians Ecoregion (Herlihy et al. 2008), only one stream (Millstone Run) was considered to be in the "Good" condition class. Both sites located on Blair Gap Run were considered to be in the "Fair" condition class whereas the JOFL site was in the "Poor" condition class.

Total taxa richness ranged from 18 (UNT to SFLCR) to 28 (Millstone Run, Table 3) in ALPO and JOFL streams. Among richness metrics, collector or filterer richness was the most uniform metric among streams and ranged only from four to six taxa. The fact that UNT to SFLCR contained only one mayfly (Ephemeroptera) and one stonefly (Plecoptera) genus was the primary reason that that stream ranked very low according to the MBII. The proportional metrics (%Non-insects and %5 dominant) and Shannon diversity and evenness metrics generally responded as expected – with increasing MBII scores, the proportional and Shannon metrics decreased and increased, respectively. Finally, as anticipated, the MTI decreased with increasing MBII scores and ranged from 3.35 (Millstone Run) to 5.38 (UNT to SFLCR). Density of BMI was considerably different among ALPO and JOFL streams and ranged from 768 m^{-2} (Blair Gap Run – Muleshoe) to 2,592 m^{-2} (Millstone Run; Figure 3).

Water Quality

Physical and chemical characteristics can vary markedly, both daily and annually. Although there are limitations to point-in-time characterizations of core water quality parameters, these measures can be helpful when evaluating patterns in biological data; moreover, extreme changes to these parameters can sometimes be detected with point-in-time samples. Water at the unnamed tributary to South Fork Little Conemaugh River at JOFL had considerably greater specific conductance (239.4 µS/cm) than the ALPO sites. Otherwise, core water quality parameters (pH, specific conductance, temperature, DO) at ALPO and JOFL sites were typical of forested watersheds with similar geologic characteristics. Relationships among core parameters were also typical – specific conductance generally increased with increasing pH (Figure 4), whereas DO concentrations more often than not decreased with increasing water temperature (Figure 5).

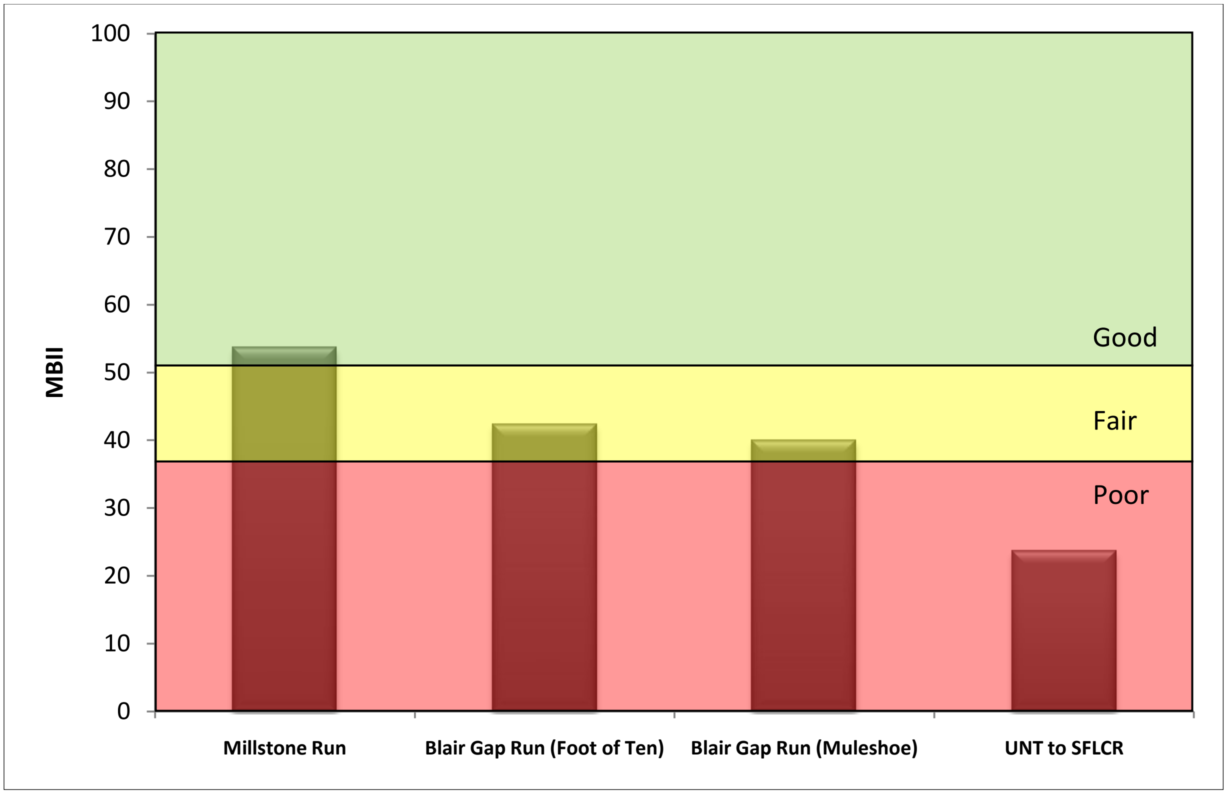

Figure 3. Macroinvertebrate Biotic Integrity Index (MBII, Klemm et al. 2003) values for benthic macroinvertebrate samples collected at sampling sites throughout Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial. Upper and lower edges of the “Fair” shaded box represent the 25th (51.0) and 5th (37.0) percentiles of index scores reported by Herlihy et al. (2008) for the Southern Appalachians Ecoregion as part of EPA’s Wadeable Streams Assessment. The Unnamed tributary to South Fork of Little Conemaugh River (UNT to SFLCR) was the only site at JOFL.

Table 2. Summary metrics and multimetric indices for benthic macroinvertebrate communities sampled at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial. Direction of metric or index response to increasing stream ecosystem integrity are denoted parenthetically by + or -. Richness metrics included total taxa richness (Total), and richness of Ephemeroptera (E), Plecoptera (P), Trichoptera (T), and Collector or Filter feeders (C-F). Proportional metrics included the percent of individuals in samples that were non-insect taxa (%Non-insects) or that comprised the combined five dominant taxa in the community (%5 dominant). Indices were the Macroinvertebrate Tolerance Index (MTI) and the Macroinvertebrate Biotic Integrity Index (MBII). The Unnamed tributary to South Fork of Little Conemaugh River (UNT to SFLCR) was the only site at JOFL.

	Richness (+)					Proportional (-)		Shannon (+)		Indices	
Stream	Total	E	P	T	C-F	%Non-insects	%5 dominant	Diversity	Evenness	MTI (-)	MBII (+)
Millstone Run	28	6	6	5	4	2	58	1.18	0.81	3.35	53.7
Blair Gap Run (Foot of Ten)	27	4	3	7	6	11	65	1.10	0.77	4.21	42.3
Blair Gap Run (Muleshoe)	25	7	4	7	6	28	59	1.18	0.84	4.41	39.9
UNT to SFLCR	18	1	1	5	4	1	85	0.76	0.60	5.38	23.6

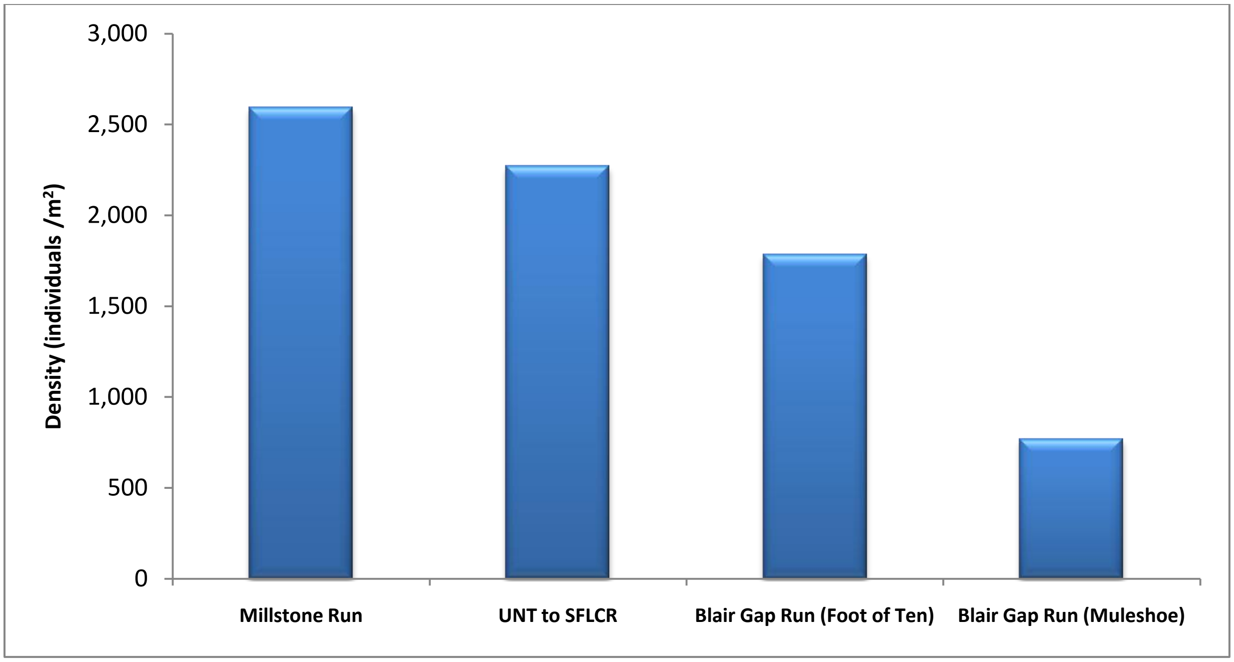

Figure 4. Density of benthic macroinvertebrates collected at sampling sites throughout the throughout Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial (JOFL) in October 2008. The Unnamed tributary to South Fork of Little Conemaugh River (UNT to SFLCR) was the only site at JOFL.

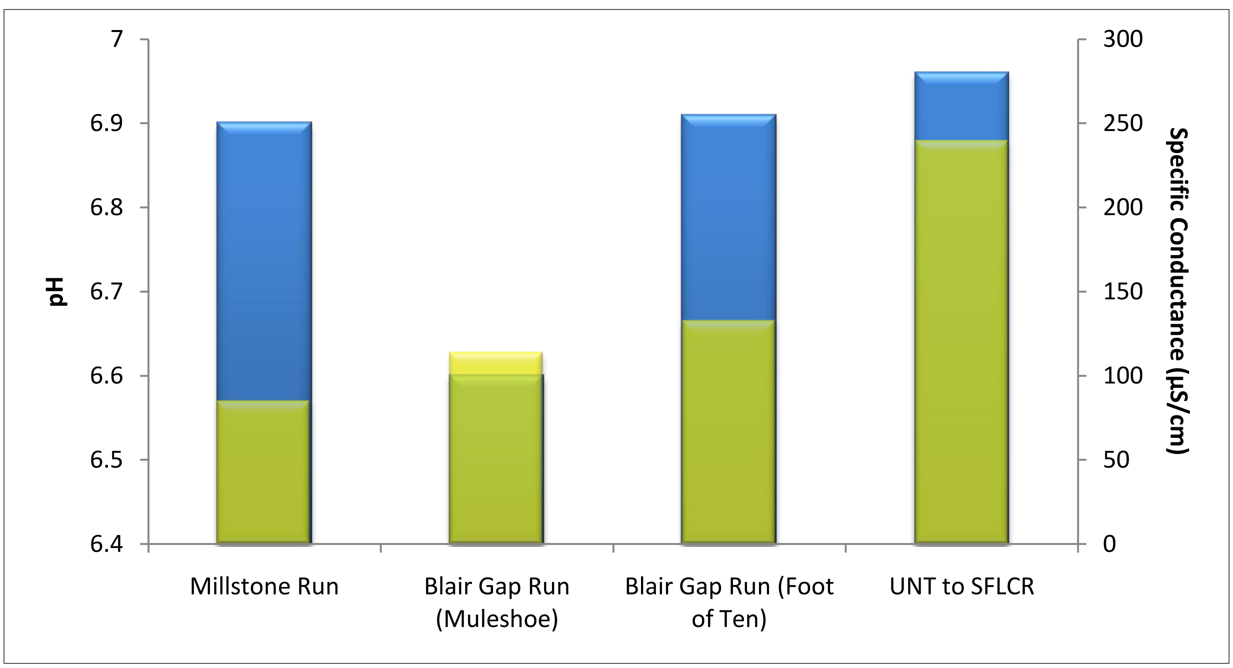

Figure 5. pH (blue bars) and specific conductance (yellow bars) of water at sampling sites throughout Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial (JOFL) in October 2008. The Unnamed tributary to South Fork of Little Conemaugh River (UNT to SFLCR) was the only site at JOFL.

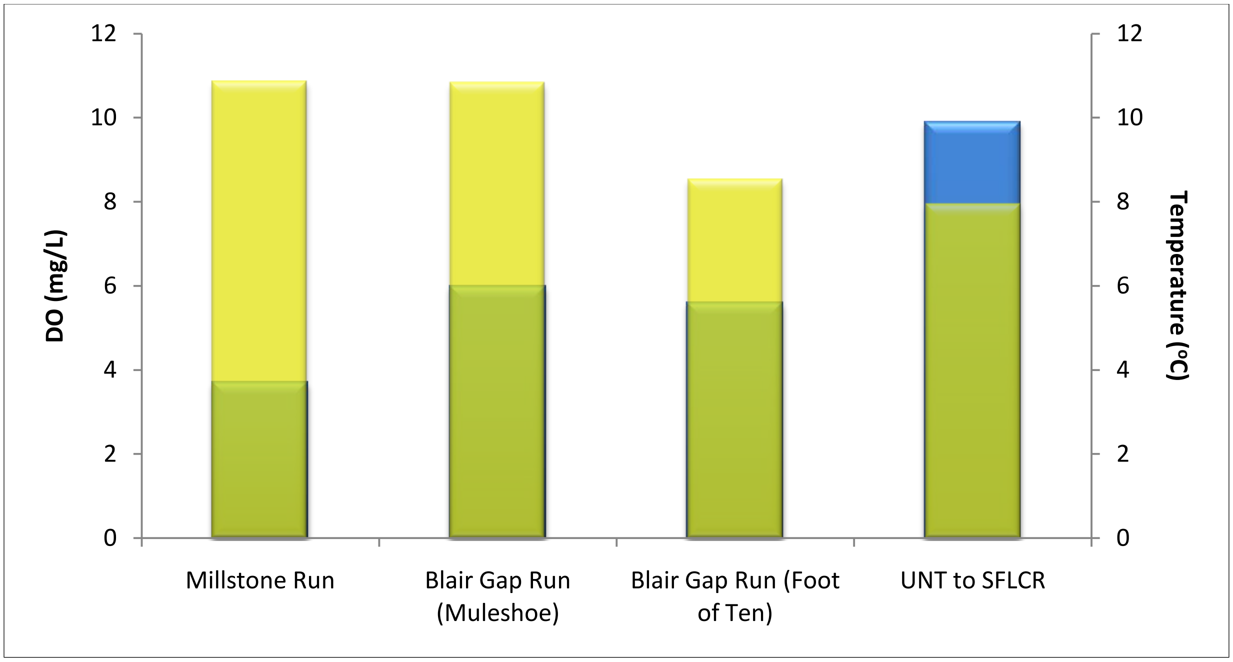

Figure 6. Dissolved oxygen concentration (yellow bars) and temperature (blue bars) of water at sampling sites throughout Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial (JOFL) in October 2008. The Unnamed tributary to South Fork of Little Conemaugh River (UNT to SFLCR) was the only site at JOFL.

Discussion

This report summarized results from the first sampling season of the ERMN BMI monitoring program at ALPO and JOFL. The effort was largely successful in that it provided quality data for all of the selected sites. All components of the protocol worked well, which was not a surprise because they were based largely on widely used USGS protocols. The primary challenge to interpreting the data (as discussed in the methods section) was that, because the ERMN protocol did not precisely follow all other state or regional protocols, comparing our data with other efforts included qualifications.

We compared ERMN results with results from the recently conducted USEPA Wadeable Streams Assessment (WSA, Figure 6). There were differences between the ERMN protocol and the WSA because of two primary decisions that were made during early stages of protocol development. These differences were: (1) ALPO and JOFL sampling was conducted during the fall whereas WSA sampling occurred during spring and early summer, and (2) the ERMN protocol currently calls for identification of chironomid midges to the family level whereas the WSA called for genus level identifications of that group. Our speculation is that those two differences resulted in conservative estimates (i.e., underestimate) of WSA condition class (i.e., good, fair, poor) for ALPO and JOFL streams based on the MBII. It should be recognized that this assessment was made based on targeted (non-random) sites; consequently, it cannot be said that these streams were representative of all ALPO and JOFL stream segments.

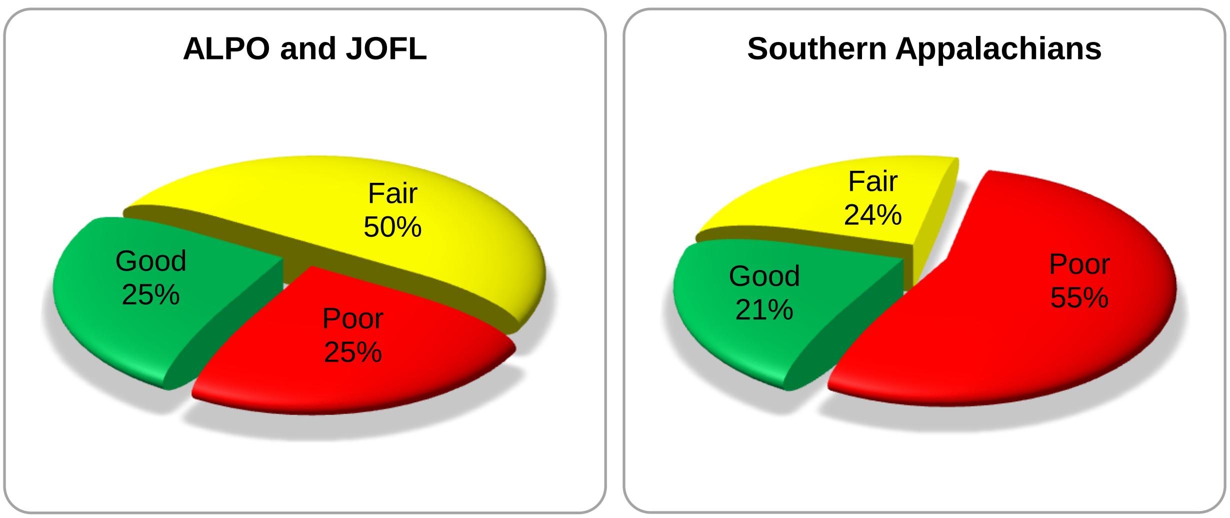

Figure 7. Condition class of randomly chosen wadeable streams throughout the Allegheny Portage Railroad National Historic Site (ALPO) and Johnstown Flood National Memorial (JOFL, left) and Southern Appalachians Ecoregion (right, modified from USEPA 2006) based on Macroinvertebrate Biotic Integrity Index values.

With each future sampling season, the ERMN BMI monitoring program will be refined and improved. It is anticipated that metrics and indices will be calibrated so that more precise and accurate comparisons can be made among ALPO and JOFL streams and streams throughout the region. In addition to calibrating the MBII and its constituent metrics, the ERMN will add other measures of stream integrity as more data are gathered. For example, another meaningful way to express BMI community condition is with Observed/Expected Indices that estimate the number of taxa (e.g., genera) that have been lost (i.e., extirpated) from a given stream (Yuan 2008). To use these methods, the expected number of taxa for a given stream type must be established from the least disturbed streams in the region. This process will likely begin after next season when assessments regarding natural variability of BMI communities can be at least coarsely made. During the next several years, we plan to cooperate with researchers from the Pennsylvania State University to standardize ERMN data to stream condition thresholds established during the WSA. That effort will allow more confident comparisons to be made between ERMN streams and similar streams throughout the ecoregion.

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